An optical and near-IR survey
of nearby clusters of galaxies

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Abstract

We present an optical and near–infrared survey of galaxies in nearby clusters aimed at determining fundamental quantities of galaxies, such as multivariate luminosity function and color distribution for each Hubble type. The main characteristics of our survey are completeness in absolute magnitude, wide wavelength coverage and faint limiting magnitudes.

1   Introduction

Because panoramic detectors have only recently been available in the near-infrared, our knowledge of infrared based quantities is extremely incomplete, even for the most fundamental quantities such as the luminosity function of galaxies (LF) and the color distribution for the different Hubble types. The cosmological importance of these quantities is further enhanced because the near-infrared domain is a good tracer of the mass distribution of galaxies (e.g. Gavazzi et al. 1996) thanks to its low sensitivity to short time-scale phenomena such as starbursts. Up to a redshift of ~ 1, the K-band samples the spectral energy distribution beyond $1\mu m$ which is basically dominated by low-mass stars (Bruzual & Charlot 1993).

The dependence of the near infrared LF on morphological type is still unknown, especially at faint luminosities, whereas a great effort is presently being made in the visible (e.g. Lobo et
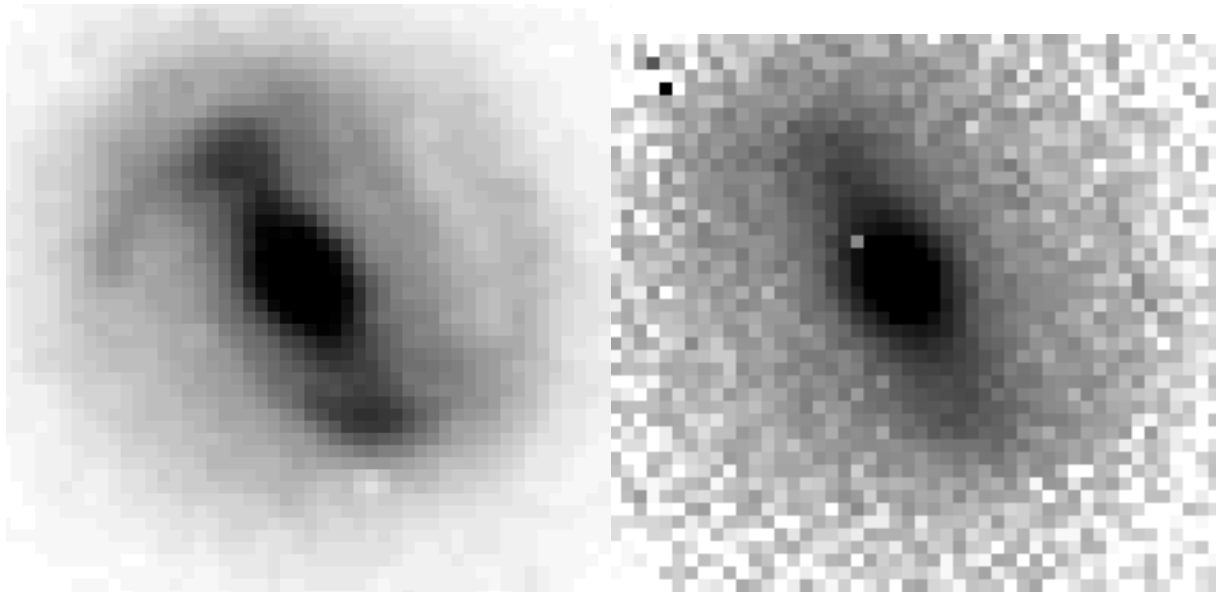
Figure 1: Comparison between the B_J (left, from POSS-II) and H (right, Moïcam data) morphologies of a galaxy in Coma. The field of view of each panel is 50 arcsec. Sampling used for this figure is 1 arcsec in B_J and in H. The H image is only preliminarily reduced.

al. 1997). The comparison between these two LFs for clusters at different redshifts can provide new constraints on the evolutionary scenarios for galaxies in clusters, in particular the evolution of the mass distribution as a function of morphological type, and the relative significance of the different interactions between cluster galaxies and their environment: merging processes (Toomre & Toomre 1972), harassment (Moore et al. 1996), ram-pressure stripping (Gunn & Gott 1972), etc. Furthermore, the nature of faint blue galaxies seen on deep galaxy counts in the blue band, and of their possible counterparts in the nearby ($z < 0.1$) universe (see the reviews by Koo & Kron, 1992, and Ellis 1997) are still an open question. Finally, the study of the global properties of galaxies in nearby clusters (color distribution, LF, segregation, etc.) is essential for comparisons with distant clusters, now observed with the Space Telescope and Keck, in order to draw an evolutionary picture.

2   Our survey

For all these reasons, we started an observational program aimed at determining basic properties of galaxies in clusters, such as multivariate luminosity functions, color distributions, type dependence of the luminosity function, spectrophotometry of the different Hubble types, etc. The main characteristics of our survey are :

- completeness in absolute magnitude,

- possibility of selecting complete samples in various filters, possibly from B_J (~ 4000 Å) to K (2.2 μm), and

- faint limiting magnitudes, in order to reach the typical luminosities of dwarf galaxies.

We are presently focusing our attention on two clusters: Coma, the observations of which are still in progress, and Abell 496, for which the analysis is underway and some preliminary results are available.

2.1   Coma

For Coma, we are presently imaging at the 2m telescope at Pic du Midi a 20×20 arcmin region, corresponding to 800×800 Kpc at the distance of Coma, in J, H and K', down to 6 mag below M^* ($B_J \sim 21$). The region is centered 15 arcmin NE from the cluster center. A preliminary analysis of the observations in H shows that the data already acquired reach the expected magnitude limit. The camera used for this survey is *Moïcam*, set at the F/8 focus, with a pixel of 0".5 and a field of 120×120 arcsec. The detector is a Nicmos with good cosmetics and linearity in the relevant intensity range, as well as a faint level of image residuals ($\leq 3\%$ between 2 successive exposures). The seeing usually ranges from <1 to 2 arcsec. For the same region, we have obtained CCD images in the optical range at the 2m telescope of Pic du Midi, as well as prime focus and large-scale photographic plates, taken with different telescopes (4m at Kitt Peak, ...) and digitized. Figure 1 shows a representative image for a relatively bright spiral galaxy (B=15 mag) in B_J (from POSS-II) and in H.

The Coma data are particularly well suited for the study and the comparison of galaxy morphologies and photometric properties in different filter-bands. In particular, we expect to measure the infrared multivariate LF down to the luminosity of dwarfs, and to obtain the color–magnitude diagram in many colors, since we have magnitudes measured from 2000 Å to 2 μ. The infrared-visual color gradients of galaxies will also be available from these data, for measuring effective radii or brightnesses, and the growth curves for different morphological types.

2.2   A496

For Abell 496, we have obtained a mosaic in K, 40×40 arcmin large, which samples not only the central part of the cluster, but also the peripheral region (up to 5 cluster core radii), allowing environmental studies. K images were taken at the 1.5m at CTIO. The images are deep enough to allow the construction of galaxy samples complete down to 5 mag below M^*. The near-infrared luminosity function of this cluster is presently available (Gardner & Annis 1997, in preparation).

In the optical, we have at our disposal three deep overlapping pointings of 14×14 arcmin taken with Mocam (Cuillandre et al. 1996) at the CFHT in the V filter. The images are very deep, and are the basis of our object catalog ($\sim 90\%$) complete down to $V = 25$ ($\sim M^* + 9$). The images were taken under good seeing conditions (0.7-0.8 arcsec FWHM) which allows an easy star–galaxy discrimination down to $V = 24$ mag. At fainter magnitudes, the contribution of stars to the sample is negligible. These images were taken through thin cirrus. In order to put the CFHT images on an absolute photometric scale, we re-observed several selected galaxies in this field at the 2m Pic du Midi telescope. The S/N ratio of these CFHT images is so good (the detection threshold at 2σ is $\mu_V = 25$ mag arcsec^{-2}) that it allows one to easily detect the large majority of low-surface brightness galaxies of the same type as those already known in Virgo (Impey, Bothun & Malin 1988) and elsewhere (Dalcanton et al. 1997).

A deep image of Abell 496 in the I filter was also taken with the UH8K camera (Cuillandre et al. 1996) at the CFHT under similar conditions. The field of view of the image is 28×28 arcmin. A CCD Schmidt frame was taken at the Calern observatory in order to photometrically calibrate this mosaic image.
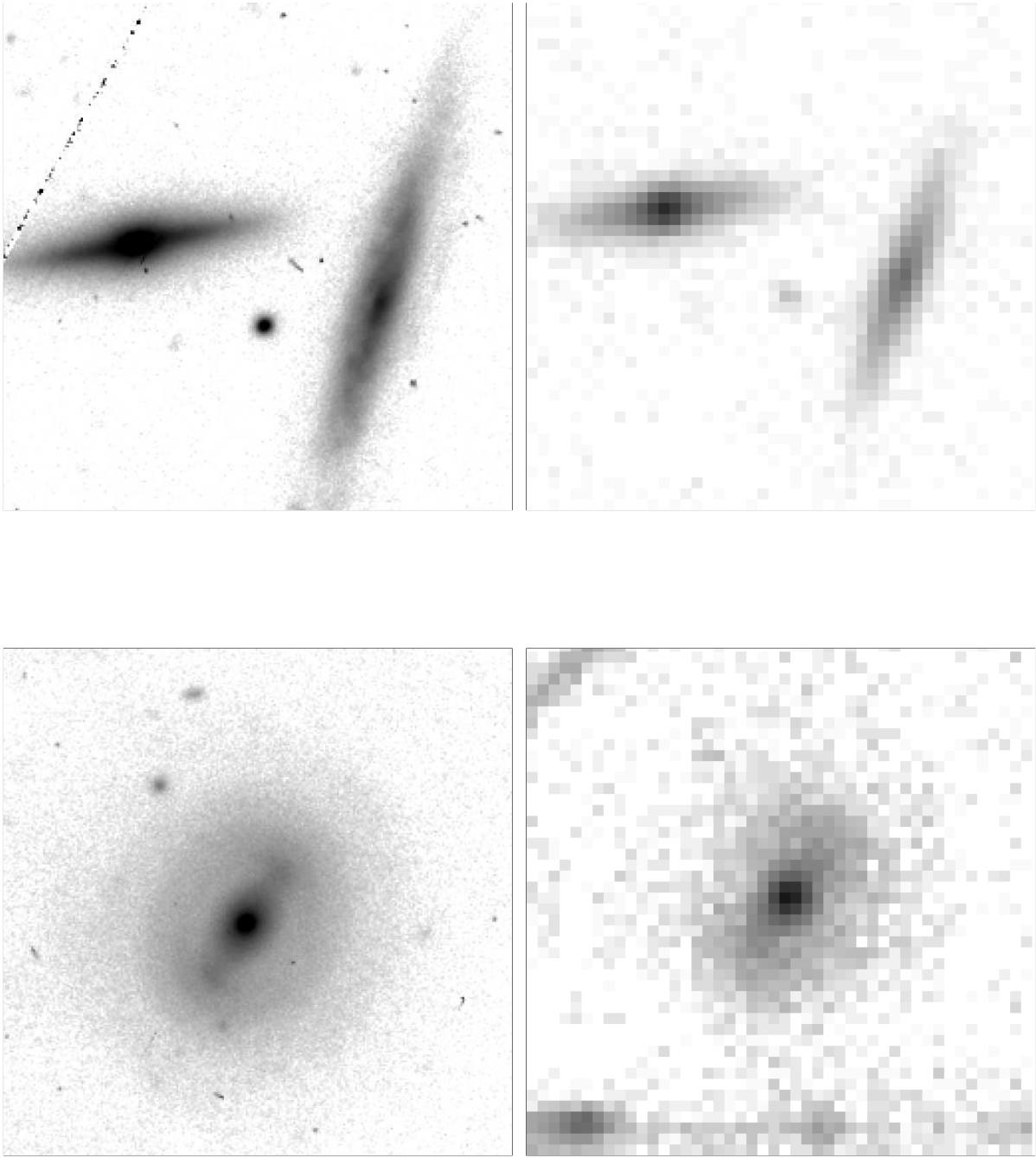
3   Preliminary results

Figure 2: Comparison between the V (left) and K (right) morphologies of galaxies in Abell 496. The field of view of each panel is 50 arcsec. The seeing is 0.7 and 1.7 arcsec for V and K respectively. The sampling is 0.2 and 1.1 arcsec for V and K.
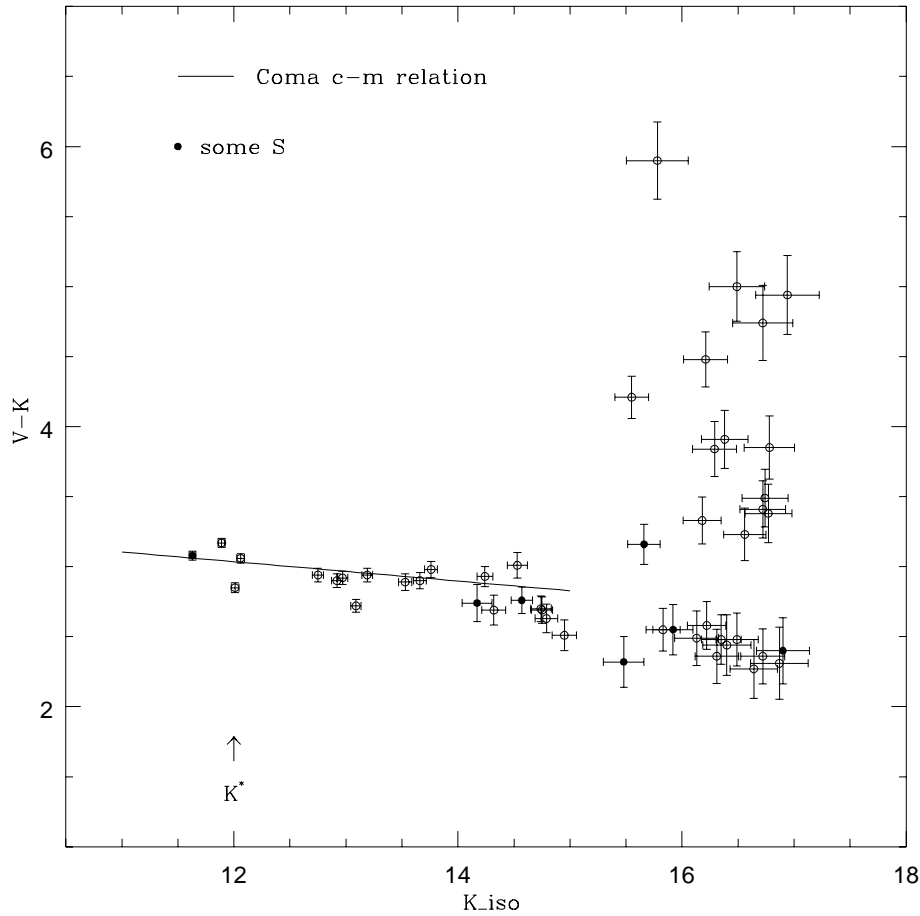
Figure 3: Color–magnitude diagram for the galaxies in the direction of the Abell 496 cluster. The sample is selected and complete in K. Filled dots are morphologically identified spiral galaxies. The plotted line is the color-magnitude relation in Coma from Bower, Lucey & Ellis (1992), corrected for the difference in distance modulus between Coma and Abell 496.

3.1 Galaxy morphology

Figure 2 shows the morphology of some typical bright galaxies of Abell 496. In general, the visual appearance in K is quite similar to that of cluster galaxies in the optical bands : bars, bulges, arms, rings and halos are present and they are in no way peculiar. The direct comparison of the morphologies in the K and V filters for the small sample of large galaxies in the central part of Abell 496 shows that all the morphological details present in V are also found in the near infrared and vice versa. In particular, none of these galaxies appears of earlier type in the infrared than in the optical. However, the sampling and seeing are much poorer in K than in V, which makes the comparison difficult, and the majority of the sample galaxies are Es or S0s, i.e. galaxies dominated by an old stellar population.

This comparison between optical and near-IR morphologies is much easier for the galaxies in Coma, as shown in the example of Figure 1. A more quantitative comparison of the morphological appearence of galaxies as a function of wavelength is presently under way.

3.2 Color–magnitude diagram

Figure 3 shows a preliminary version of the color-magnitude diagram of galaxies in the central part of Abell 496. The sample is selected and complete in the K filter. Colors are measured within a 4 arcsec aperture (3.7 kpc for galaxies in the Abell 496 cluster), which only includes the central part of the brightest galaxies but all the $S/N > 1$ region of faint galaxies. At the brightest magnitudes, the color magnitude relation of Abell 496 is in excellent agreement with that of Coma (Bower, Lucey & Ellis 1992), which is plotted in the figure as a line, after correction for the difference in distance modulus between the two clusters. The scatter is small, 0.2 mag, and not much larger than the photometric errors. At faint magnitudes, there is a population of red (say $3 \lesssim V - K \lesssim 6$) galaxies. Such extremely red galaxies are also found in multicolor field surveys (e.g. Moustakas et al. 1997), but at fainter magnitudes (K=19-20), and they are identified in this case to early-type galaxies having undergone a burst of star formation at z>5 and viewed at z~1. Their total number in the field of Abell 496 is of the same order as that expected for the background (according to the field counts by Gardner et al. 1996). Nevertheless, we cannot exclude that at least some of these galaxies belong to the cluster. A straightforward calculation shows that a dusty Sb/Sc galaxy, with $A_V \sim 1 - 2$, will have $V - K \sim 3.7$ to 5. While waiting for a spectroscopic confirmation, we can discriminate between the two hypotheses by studying the clustercentric radial dependence of the density of these galaxies.

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